The Spectrum of the 1/4 keV Band Diffuse Soft X-ray Background

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Abstract:

The spectrum in the 145–284 eV (42–85 Angstrom) band of a portion of the diffuse x-ray sky was obtained in 1993 by the Diffuse X-ray Spectrometer. We compare these data to a model including a computation of the spectra of a few ions due to solar wind charge exchange in the heliosphere, obtaining solar wind parameter ranges by studying the in situ observations at a similar phase in the solar cycle, i.e. in 2003. The one spectral feature which is consistent with an unblended, isolated line is coincident with the hydrogenic oxygen Balmer gamma (n=5 to 2) transition, which should be strongly pumped by charge exchange.

The DXS Instrument

- The Diffuse X-ray Spectrometer (DXS) was an attached Space Shuttle payload that flew on STS-53 in for six days in 1993 January.
- DXS is a Bragg crystal spectrometer, which uses a large area proportional counter as a detector.
- The detector assembly rotates, allowing full wavelength coverage of a $15^\circ \times 150^\circ$ patch of sky, in the wavelength band 42–85 Å(145–284 eV). Spatial resolution is 15°.
- DXS has a resolving power of $\lambda/\Delta\lambda \approx 35$, and a throughput $A\Omega \approx 0.02$ cm^2 sr.
- The scan path included the Vela and Monogem Ring supernova remnants.
- We analyze the spectrum of the sky between the supernova remnants, for a fair sample of the Diffuse Soft X-ray Background sky.

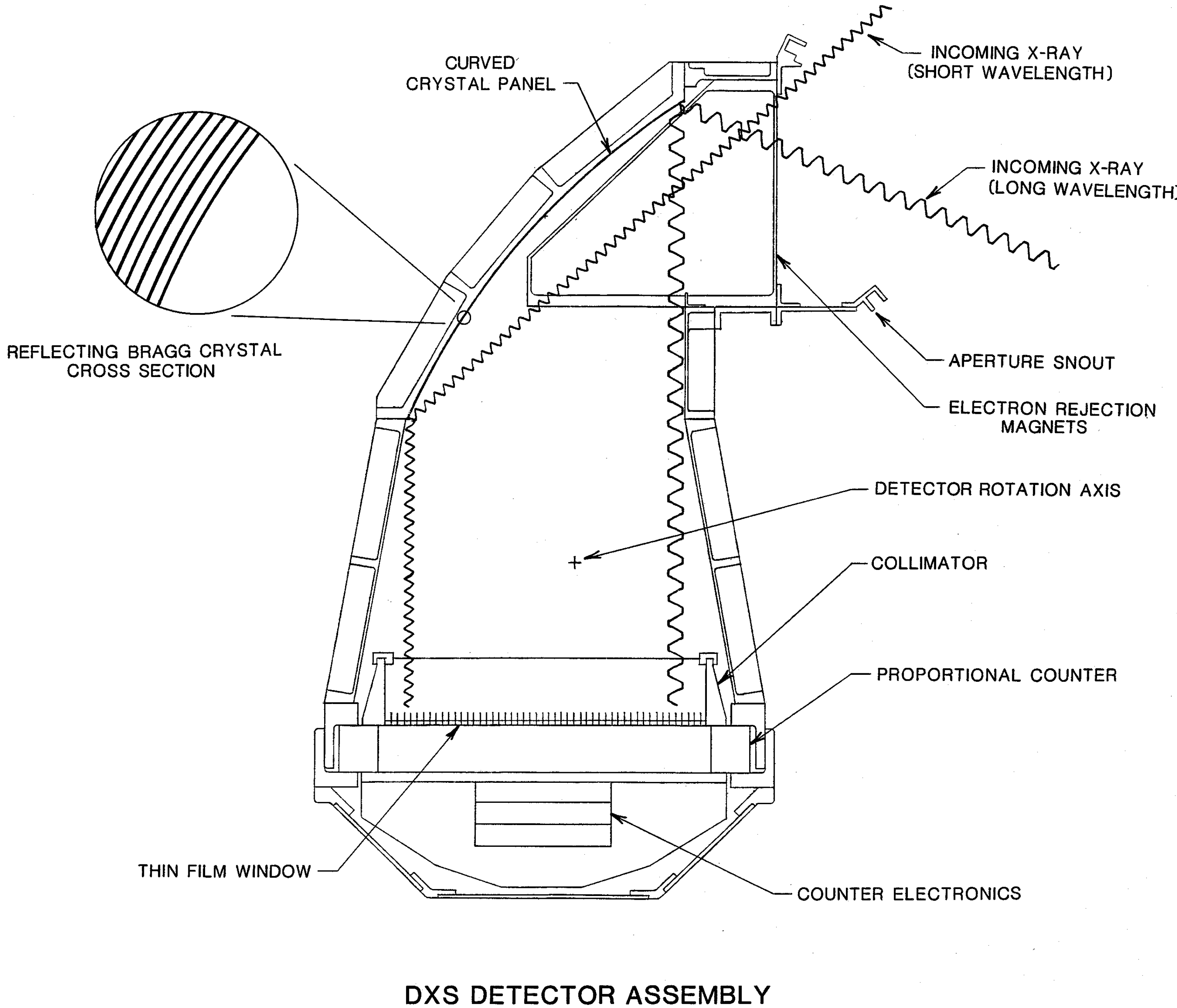

Figure 1: Cross section of the DXS instrument

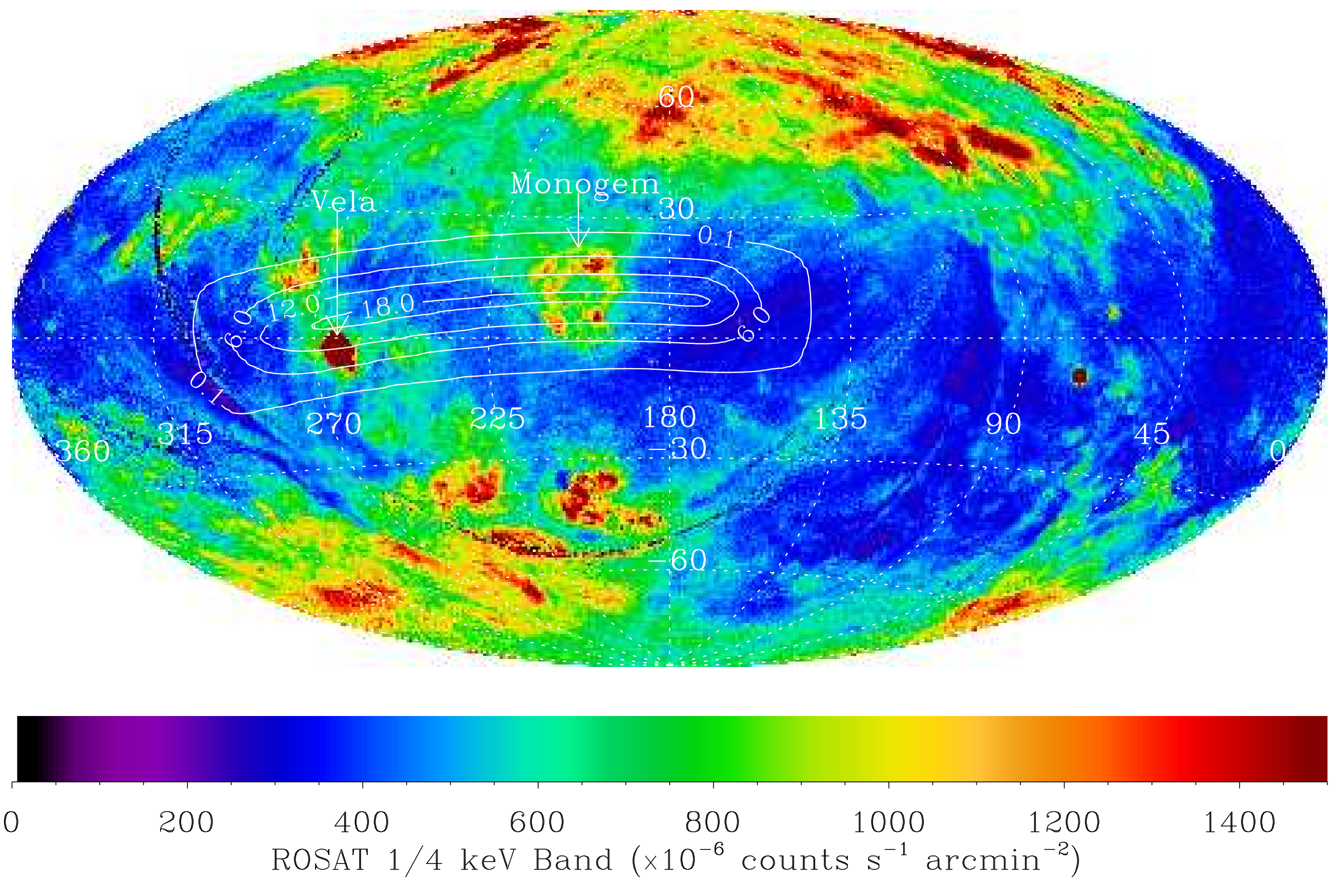

Figure 2: DXS Scan path on Rosat 1/4 keV sky map, in 180°-centered galactic coordinates.

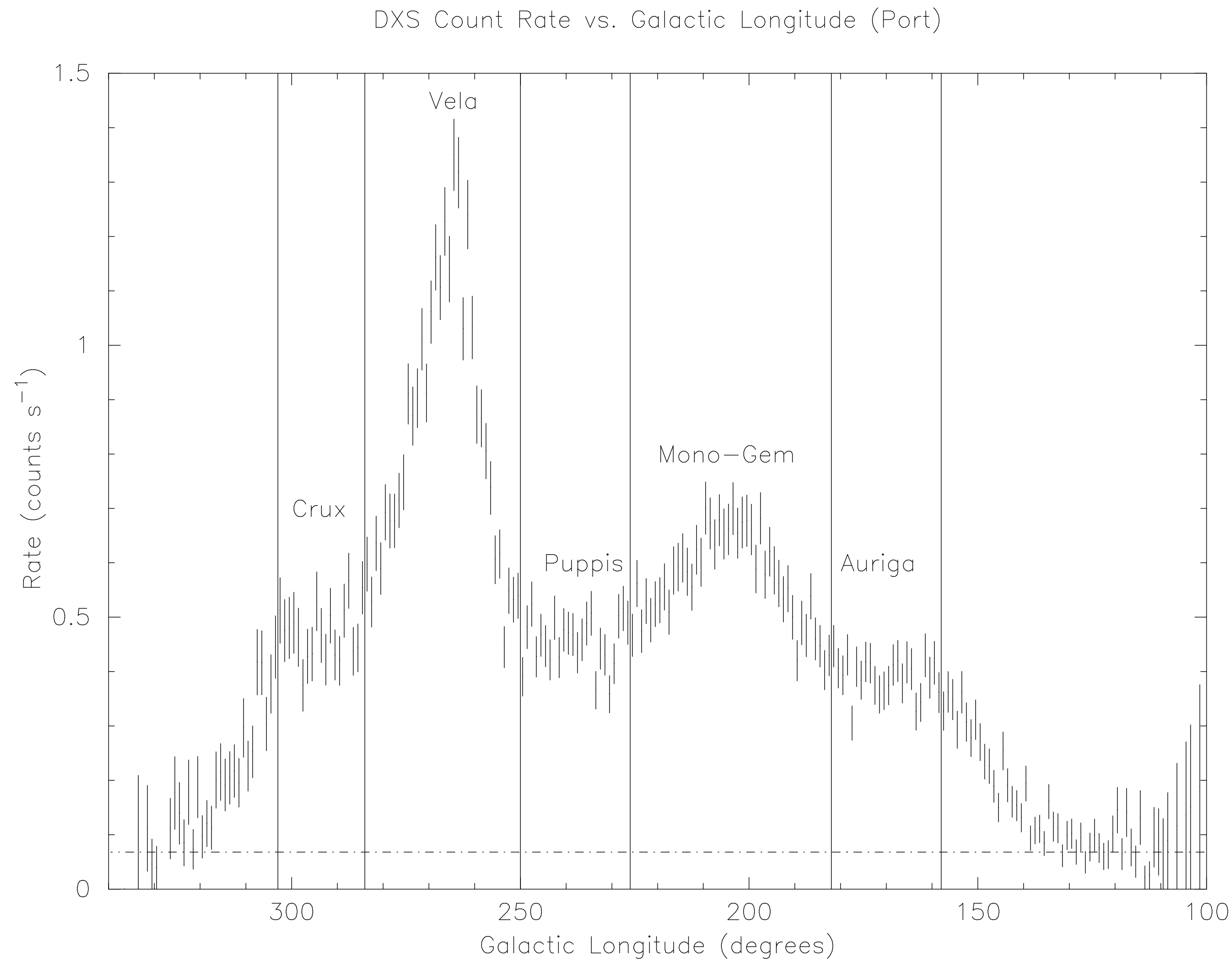

Figure 3: DXS count rate vs. Galactic Longitude

Spectral nalysis

- The spectrum of all sky regions other than Vela and the MonoGem Ring is presented below.
- Thermal models to not fit well, but this is likely because of the iffy state of the atomic physics as much as the hypothesis of hot gas emission of the x-rays.
- We need careful calculations of electron impact excitation and x-ray emission of L-shell ions of Si, S, Mg, and Ne, and M-shell ions of Fe.

- One feature, at $\lambda 67.4$ Å (184.0 eV), is consistent with an isolated, unblended spectral line. We derive a line strength of 1.45 ± 0.14 photon cm^{-2} s^{-1} sr^{-1}
- This is also the wavelength of the O VIII (O^{+7}, i.e. hydrogenic) Balmer γ line ($n = 5 \rightarrow 2$).
- All other attempted identifications of this feature have failed, in most cases due to the prediction of a stronger line elsewhere in the band that is not observed.
- Balmer β, γ and δ lines, with equal intensity and convolved with the instrument response, are superimposed on the spectrum.
- Wargelin et al and Pepino, Kharchenko and Dalgarno give calculations of charge exchange cross sections and branching ratios for several oxygen and neon ions.

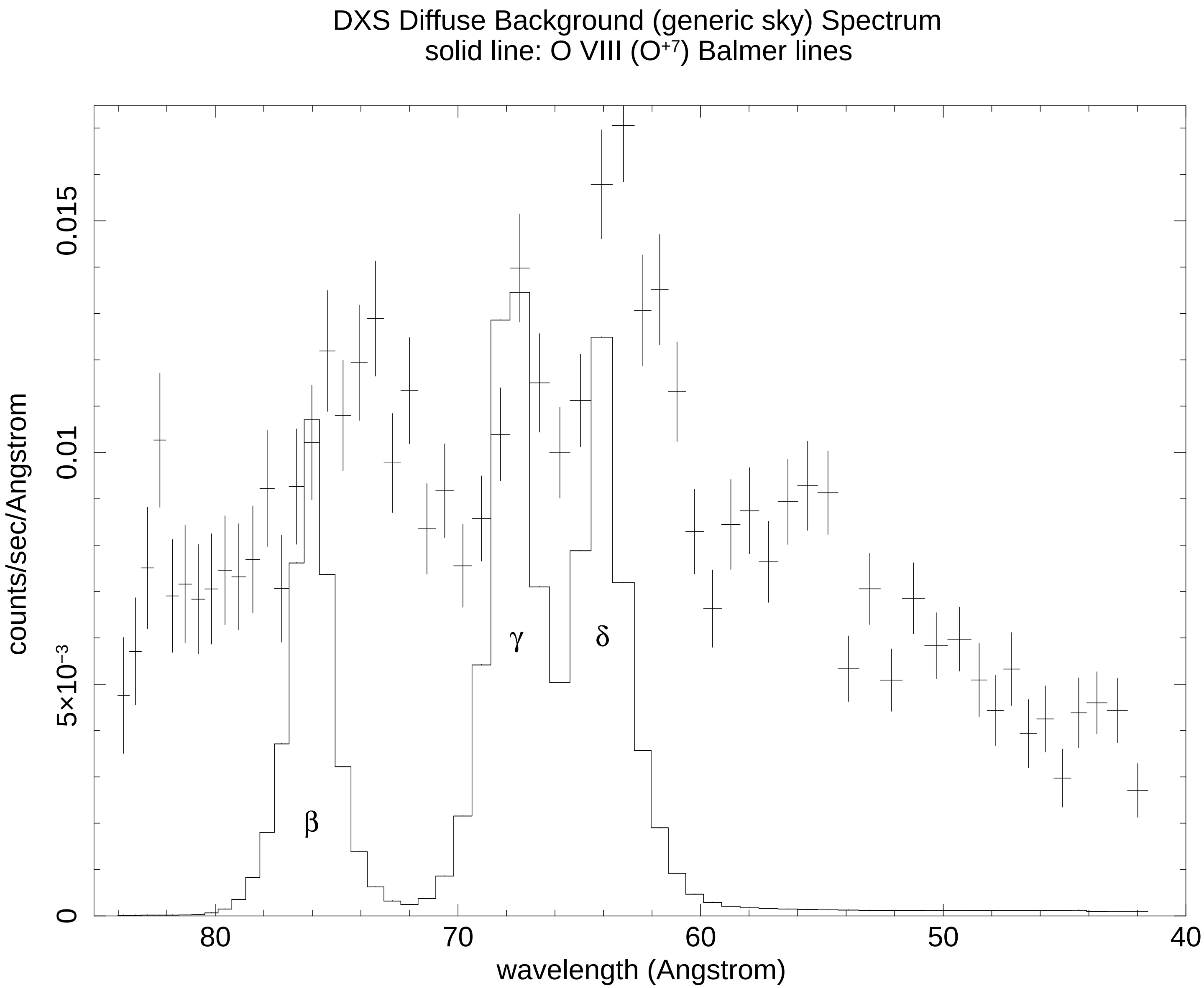

Figure 4: DXS generic sky spectrum, with model O VIII lines. Note good agreement between the γ line and the data.

Charge Exchange: a Plausibility rgument

- Solar wind ions can charge exchange with interstellar neutrals in the heliosphere. De-excitation then produces x-rays. This mechanism also produces cometary x-ray emission.
- For example: $\mathrm{O}^{+8} + \mathrm{H}^0 \rightarrow \mathrm{O}^{+7*} + \mathrm{H}^+$
- The surface brightness in a line is given by

$$\Sigma = \frac{1}{4\pi} \int n_{sw} n_{ism} v_{sw} \sigma y \; dl$$

  where

  - n_{ism} is the density of neutrals from the interstellar medium, **here assumed constant**;
  - n_{sw} is the density of the ion in question in the solar wind;
  - v_{sw} is the solar wind speed (taken to be that of the protons);
  - σ and y are the cross section and line yield, respectively; and
  - The integral dl is along the line of sight.

- the ACE satellite was launched to the Sun-Earth L1 point in 1997, after the end of the DXS mission.
- We therefore look at the corresponding phase of the *following* solar cycle, in calendar year 2003, for data on the ionization structure of the solar wind.

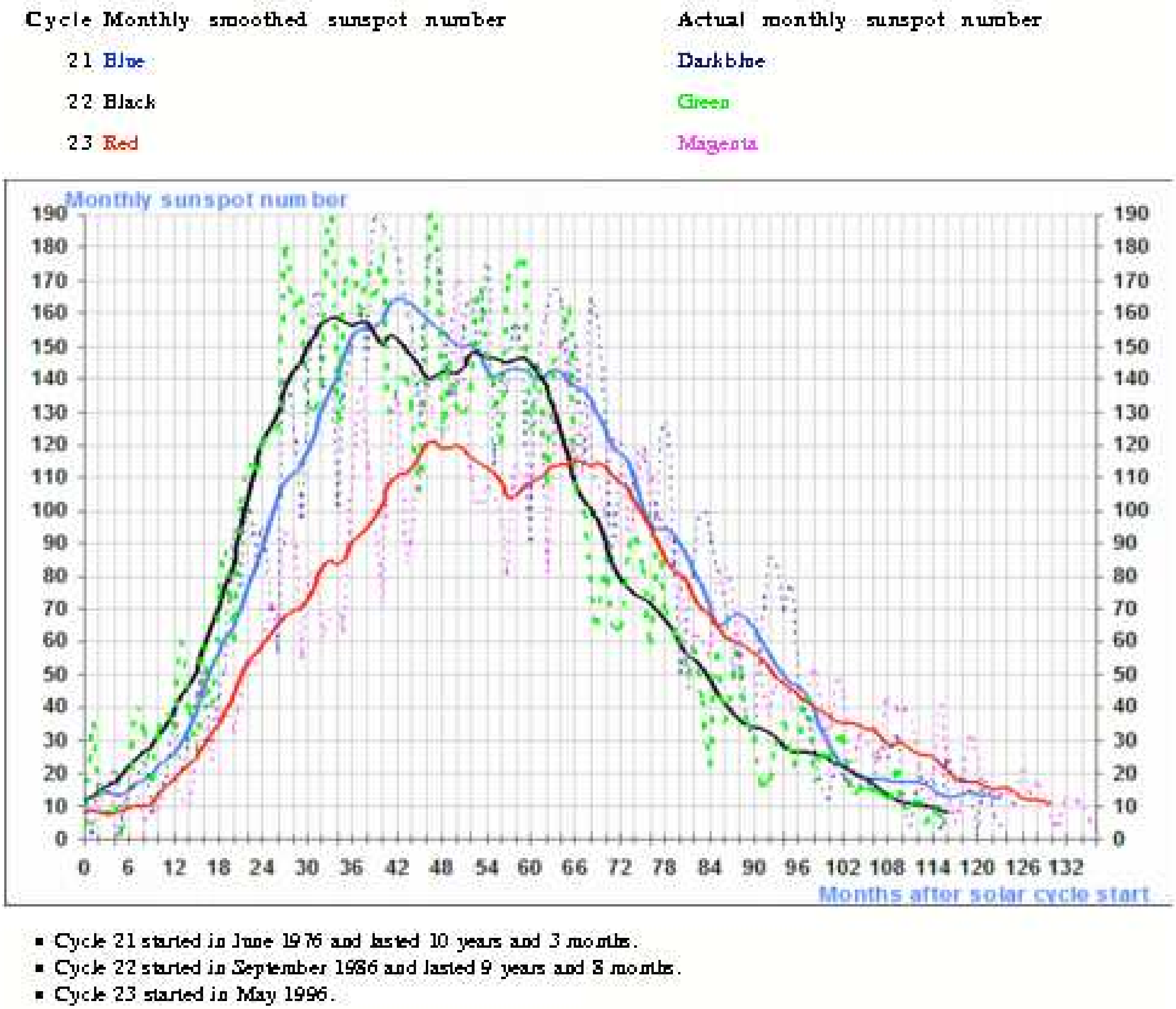

Figure 5: Sunspot numbers for 3 solar cycles. DXS flew in month 77 of cycle 22. The following cycle, 23, has corresponding sunspot numbers for roughly the calendar year 2003.

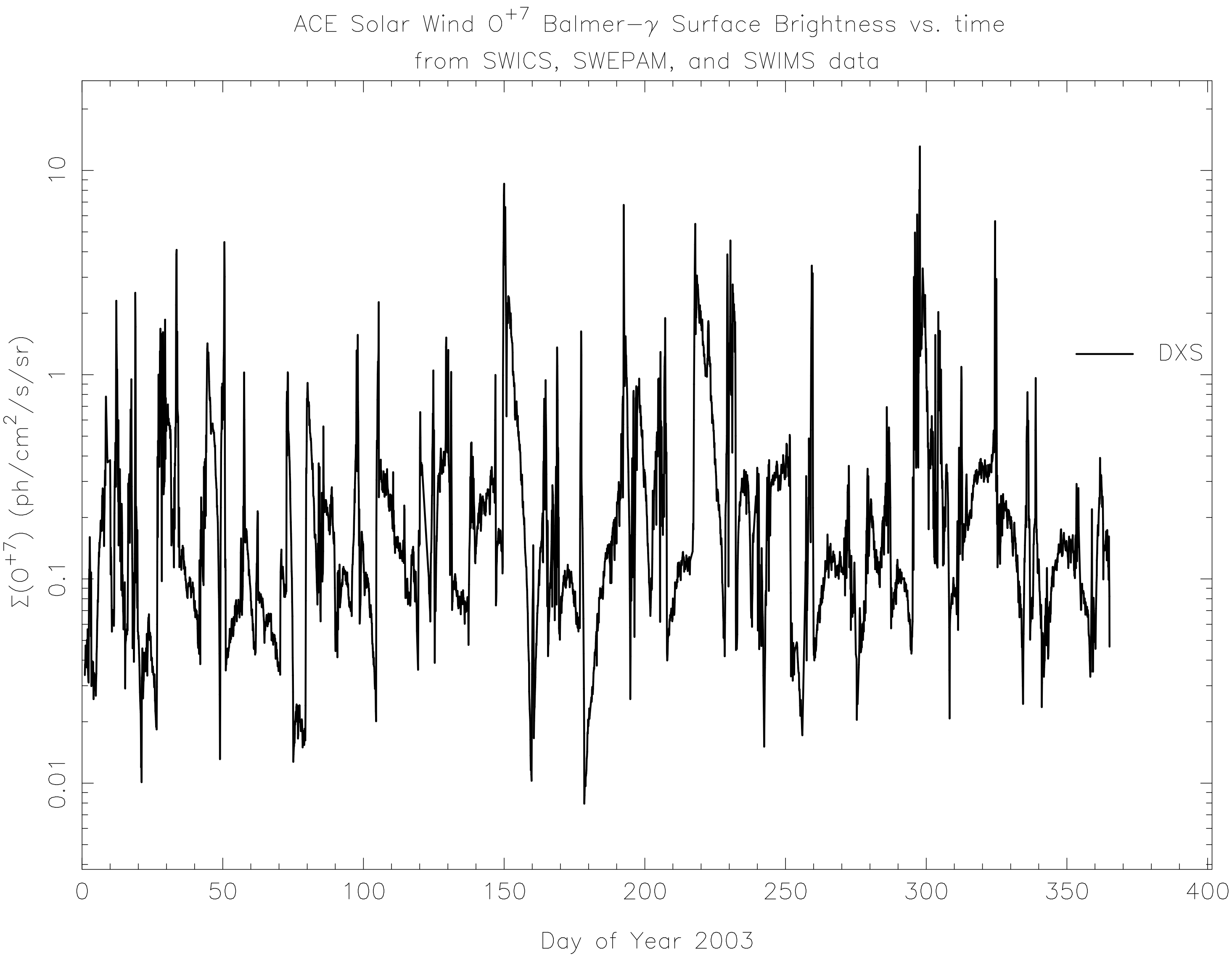

Figure 6: Estimated surface brightness of O VIII Balmer γ vs. time for calendar year 2003. The DXS detection of this line is marked in the right margin.

Charge Exchange: a Plausibility rgument

- This study, while suggestive, is not definitive.
- Most of the spectrum is still unexplained. Atomic data are needed for thermal excitation and charge exchange for ions such as Si VIII, S VIII, Mg IX, and Fe X (plus or minus an ion stage or two). Such data may also lead to another plausible identification for this spectral feature.
- We've assumed the interstellar gas is unaffected by its passage through the heliosphere. Better models of this exist. In fact, the some of the sightlines passed near the He focusing cone, downwind from the sun.

ll that said...

- **For only $\approx 6\%$ of the time in 2003 would DXS have observed an O VIII Balmer γ line as bright as it saw in 1993 January.** Bare oxygen ions are rare in the solar wind.
- Unless a more careful computation changes the predictions significantly, it seems unlikely that the line in the DXS spectrum is heliospheric in origin.
- This conclusion supports the presence of hot gas in the nearby interstellar medium (nearer than $N_H \sim 10^{20}\mathrm{cm}^{-2}$ of neutral hydrogen).

References

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